International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 1535-1540

AN EFFECT OF ANKLE FOOT ORTHOSIS ON THE MUSCLE ACTIVITY OF DROP FOOT PATIENT: A CASE STUDY

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ABSTRACT

This paper presents a case study for a drop foot patient, analyzing the muscle activation via electromyography (EMG)while using different types of ankle foot orthosis (AFO) and compare it with muscle activity of bare foot movement during stair climbing and gait. EMG activity in stair climbing and gait was recorded without and with wearing three types of AFO materials (Polypropylene (PP), carbon fiber composite material (CF), Polylactic Acid(PLA)) under different backpack load (0 Kg, 5 kg, 10 kg, 25 kg). EMG signals recorded from the two lower limb muscles (gastrocnemius and tibialis anterior) showed that amplitude of EMG increased with increasing load during stair climbing and gait. The Normalized EMG-RMS (NER) of both the muscle group was greater instair climbing compared to gait. NER of gastrocnemius was greater than tibialis anterior for both the task under the same load condition. While using PLA-AFO on drop foot lower limb, the NER of both the muscle was comparable to the NER value of normal limb in both the task. The study of muscle activation under different backpack load during stair climbing can be used to design orthoses device and interface with intelligent control based on EMG for human activities lower muscle.

KEYWORDS*: *Normalizing, Muscle Activation, Backpack Load, Electromyography (EMG) & Ankle Foot Orthoses (AFO)

Received: Apr 21, 2019; **Accepted**: May 11, 2019; **Published**: Jun 11, 2019; **Paper Id.**: IJMPERDJUN2019161

A CASE STUDY

INTRODUCTION

Walking and stair climbing are common tasks encountered in day to day living. Manifesting these tasks are highly dependent on the strength and functioning of lower limb [1], [2], [3], [4], [5]. Researchers have studied the effectsof step height [6], gait velocity [7], age [8] and staircase aberration on lower limb biomechanics [9]. Both endo and exo-orthosis have proven their efficacy in improving patient gait suffering from lower limb pathology. Studies have shown the positive changes in gait ability of patients with knee and hip implants [11], [12], amputees with artificial limbs [13] and athletes with anterior cruciate ligament deficiencies [14]. Study have also been conducted to show the effect of orthosis material on gait kinematics[10].

Drop foot is the abnormality in gait caused due to improper flexion of the ankle and is commonly occurred after stroke, spinal cord injury, or other nervous disorders. In drop foot, the patient is unable to lift the affected feet which results in dragging of ankle during the swing phase of the gait cycle. Various powered and non-powered ankle foot orthosis (AFO) are available which are used to treat the pathology and support the foot during swing phase. However the AFO are sometimes found uncomfortable to the patient and does not promote

muscle atrophy [15]. Hence it is important to study the muscle activation while using these AFOs.

Surface Electromyography (EMG) provides a non-invasive way to investigate the muscular effort in the form of summed action potentials. EMG have been used to provide both the insight into neuralcontrol strategies for different tasks in gait cycle [1], [16], [17] as well as, to indicate the knee joint loadings at the knee due to increased knee height [18].

In the present paper a case study has been presented for the muscle activity of gastrocnemius and tibialis anterior of the drop foot patient while using three different types of AFO with four different backpack loading conditions and compared it with the muscle activity of normal foot.

METHODOLOGY

A drop foot patient (age = 24 years, height = 160 cm and weight = 56 kg) was recruited for the case study through local advertisement. The patient suffered drop foot in right leg and have never used any orthotic aid to support the drop foot. The study was approved by the university ethics board and a written consent was taken from the subject after explaining the experimental task.

Ankle Foot Orthosis (AFO)

Three different types of AFO viz. Polypropylene (PP), carbon fiber composite (CF) and Polylactic Acid (PLA) were tested and compared with the bare foot condition during gait and stair climbing task. Figure 1shows the different AFO used for the study.

Figure 1: Ankle Foot Orthosis- (a) PP, (b) CF and (c) PLA

Design of Experiment

The experiment consisted of measuring the EMG activity of Gastrocnemius (GA) and Tibialis anterior (TA) of the right leg (affected with drop foot) during gait and stair climbing task with and without (bare foot) the AFOs. The two tasks were carried out at five different backpack load conditions viz. 0 kg (without backpack), 5 kg, 10 kg and 25 kg. Between each loading condition a time gap of 5 minutes was given to subside fatigue. The stair climb (rise = 180 mm, tread = 280 mm, width = 450 mm) consisted of climbing 6 stairs in a row without any hand support while, the gait task consisted of subject performing the gait at his normal pace for 2.5 meters (the distance was marked on the ground). In a separate trial the two tasks were conducted to record the muscle activity of GA and TA of patient's left leg (unaffected leg) in bare foot condition to allow comparison with the drop foot muscle activity while using different AFO and loading conditions.

EMG Instrumentation and Data Acquisition

EMG was measured with the aid of bipolar active EMG electrodes (SX230, Biometrics Ltd, UK). The electrodes were pre amplified with biometrics subject unit and base unit (Biometrics DLK 900). The EMG data was recorded at sampling frequency of 1000 Hz into the PC using Data LINK acquisition software. Reference electrode was attached to the lunate bone of the right wrist.

Procedure

First the participant was given introduction to the AFO and briefed about the experimental purpose. Skin preparation was done before placing the EMG sensors over the tested muscle groups as per the SENIAM standards. With each loading condition the subject was asked to carry the backpack on his shoulder and carry out the gait and stair climb task while the EMG data is continuously recorded in the PC. Figure 2shows the patient performing the two tasks. After recording the muscle activity of affected foot (drop foot) for the two task in different loading and AFO, trials were conducted to record the EMG activity of GA and TA of unaffected leg for different backpack loads in bare foot condition.

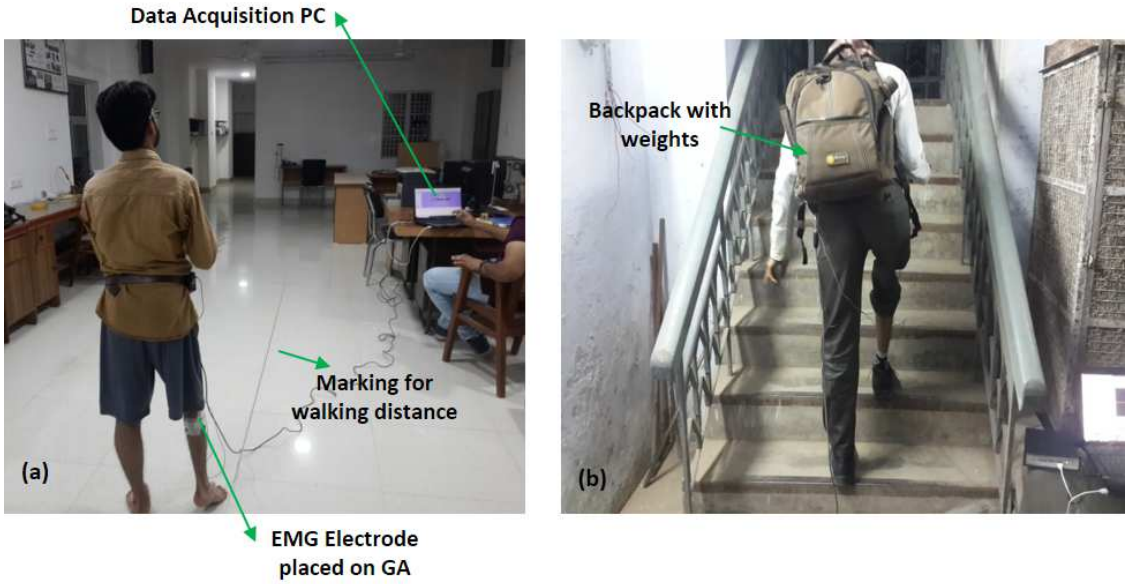

Figure 2: Patient Performing (a) Gait and (b) Stair Climb Task

Approach for the Analysis

After completion of the experimental trial, post processing of the EMG data was done with Data LINK PC software. Root mean square (RMS) of the EMG data were evaluated for successive time strap of 125 ms and then normalized using peak dynamic normalization method.

$$\text{nRMS} = \frac{(\text{RMS}_{\text{EMG}})_{\text{mean}} - (\text{RMS}_{\text{EMG}})_{\text{min}}}{(\text{RMS}_{\text{EMG}})_{\text{max}} - (\text{RMS}_{\text{EMG}})_{\text{min}}}, \quad (1)$$

Where, nRMS= Normalized RMS

$(\text{RMS}_{\text{EMG}})_{\text{mean}}$ = Mean EMG-RMS during the task.

$(\text{RMS}_{\text{EMG}})_{\text{min}}$ = Minimum EMG-RMS during task.

$(\text{RMS}_{\text{EMG}})_{\text{max}}$ = Maximum EMG-RMS during the task.

RESULTS

A sample result for the recorded EMG data and evaluated EMG-RMS for patient wearing CF AFO with 10 Kg load for gait and stair climbing task is shown in Figure 3. The results showed that muscle activation EMG amplitudes of both the muscles in the tasks increases with increasing backpack loads. The maximum EMG-RMS of GA was greater than TA for both the gait and stair climbing task for all the AFO tested as well as for bare foot. Figure 4 summarizes the normalized EMG-RMS (NER) for different experimental conditions.

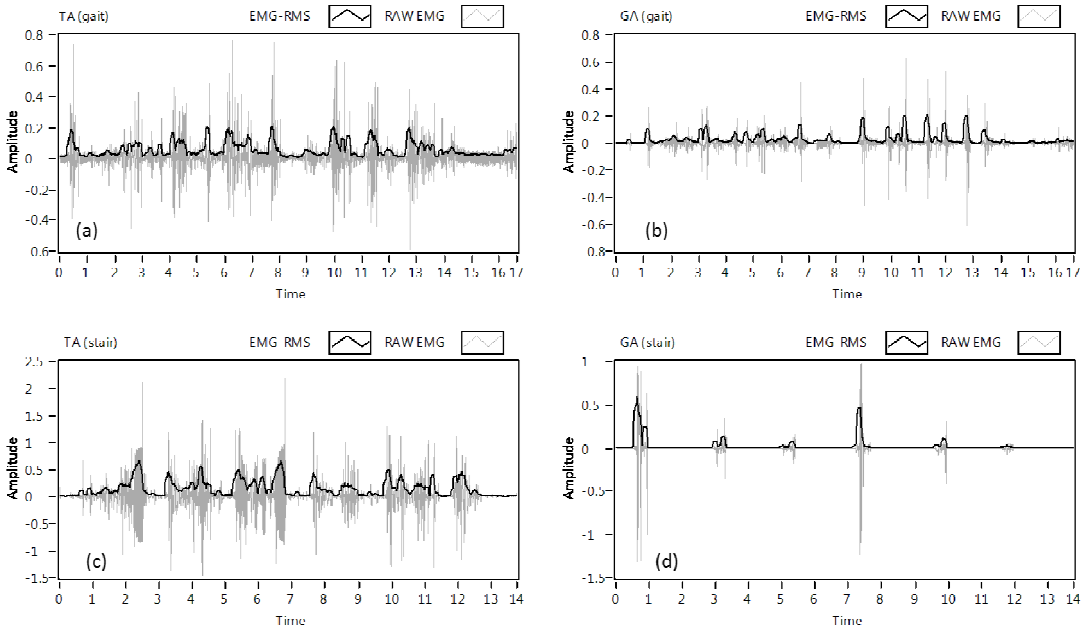

Figure 3: EMG-RMS Data for TA and GA During Gait(a, b) and Stair Climb (c,d) Respectively for Patient Wearing CF AFO and Backpack Load of 10 kg

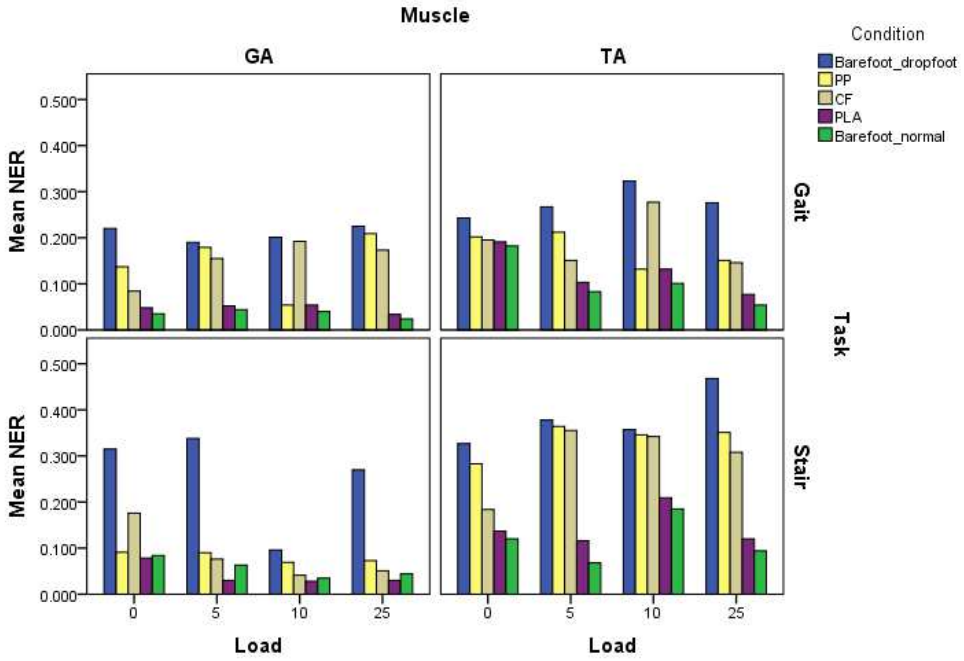

Figure 4: Normalized EMG RMS (NER) for the Tested Loads and AFOs

CONCLUSIONS

The Normalized EMG-RMS (NER) of both the muscle group was greater in stair climbing compared to gait. NER of gastrocnemius was greater than tibialis anterior for both the task under the same load condition. While using PLA-AFO on drop foot lower limb, the NER of both the muscle was comparable to the NER value of normal limb in both the task.

REFERENCES

1. *G., Graichen F., Rohlmann A.(1995) : Is staircase walking a risk for the fixation of hip implants. J, Biomech, [1] Andriacchi, T.P., Andersson, G.B.J., Fermier R.W., Stern, D., &Galante J.O.(1980) : A study of lower-limb mechanics during stairclimbing.J, Bone Joint Surg, 62, 749–757*
2. *Andriacchi T.P., Galante J.O., &Fermier R.W.(1982): The influence of total knee-replacement design on walking and stair climbing.J, Bone Joint Surg, 64, 1328–1335*
3. *Bergmann G., Graichen F., Rohlmann A.(1995) : Is staircase walking a risk for the fixation of hip implants. J, Biomech, 5, 535–553*
4. *Haightd.J., Lerner Z.F., Board W.J.(2014) : A comparison of slow, uphill and fast, level walking on lower extremity biomechanics and tibiofemoral joint loading in obeseand nonobese adults. J. Orthop. Res, 32(2), 324–330.*
5. *Townsend M.A., Lainhart S.P., Shiavi R. (1978) :Variability and biomechanics of synergy patterns of some lower-limb muscles during ascending and descending stairs and level walking. Med. Biol. Eng. Comput, 16, 681– 688*
6. *Spanjaard M., Reeves N.D., Van dieen J.H., Baltzopoulos V., Maganaries C.N.(2008) : Lower-limb biomechanics during stair descent. J. Exp. Biol, 211, 1368–1375*
7. *Spanjaard M., Reeves N.D., Van dieen J.H., Baltzopoulos V., Maganaries C.N. (2009) :Influence of gait velocity on gastronomies muscle fascicle behavior during stair negotiation, J. Electromyogr. Kinesiol, 19, 304–313*
8. *Nadeau S., Mcfadyen B.J., Malouin F.(2003) : Frontal and sagittal plane analyses of the stair climbing task in healthy adults aged over 40 years, Clin. Biomech, 18, 950–959*
9. *Riener R., Rabuffetti M., Frigo C.(2002) : Stair ascent and descent at different inclinations, Gait and Posture, 15, 32–44*
10. *AbdulsadahF.H, Murataza Q, Hasan F,Hussain K. M. (2018): Improvement in Gait Cycle with Ankle Foot Orthosis, HWWE 2018, Kerela, India.*
11. *Blazkiewicz M.(2013): Muscle force distribution during forward and backward locomotion, ActaBioeng. Biomech,15, 3–9*
12. *Costigan P.A., D Eluzio K.J., Wyss U.P.(2006): Knee and hip kinetics during normal stair climbing, Gait and Posture, 16, 31–37*
13. *Powers C.M., Boyd L.A., Torburn L. Perry J. (1997): Stair ambulation in persons with transtibial amputation, J. Rehabil. Res. Dev, 34, 9–18*
14. *Kowalk D.L., Duncan J.A. Mccue F.C., Vaughan C.L.(1997) : Anterior cruciate ligament reconstruction and joint dynamics during stair climbing, Med. Sci. Sports Exerc, 29, 1406–1413*
15. *Hoque, L., Kamal, S. M., & Ahmed, Z. (2013). Isolation, identification and antimicrobial sensitivity pattern of bacterial isolates from tracheal aspirate of ICU patients of central Dhaka, Bandladesh. Int j res appl nat soc sci, 1(7), 11-6.*

16. *Hesse S., Werner C., Matthias K., Stephen K., Berteanu M. (1999): Non-velocity-related effects of a rigid double-stopped ankle–foot orthosis on gait and lower limb muscle activity of hemiparetic subjects with an equinovarus deformity, Stroke, 30, 1855–1861.*

17. *Silder A., Besier T., Delp S.L.(2012) : Predicting the metabolic cost of incline walking from muscle activity and walking mechanics, J. Biomech, 45, 1842–1849*

18. *Sutherland D.H.(2001) : The evolution of clinical gait analysis, Kinesiological EMG, Gait and Posture, 14, 61–70*

19. *Barkema D.D., Derrick T.R., Martin P.E.(2012) : Heel height affects lower extremity frontal plane joint moments during walking, Gait Posture, 35, 483–488*